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ABSTRACT

The purpose of this study was to explore how the needs, actions, and beliefs of teacher and students interact with the constraints of the classroom and the curriculum to establish an atmosphere conducive to effective learning of physics in grade 11. An interpretive research methodology was used to investigate the students' and teachers' needs, ideas, and beliefs which were responsible for the coherent establishment of a harmonious student-centered teaching-learning environment. Constraints within the curriculum and the school were examined for their impact on the learning climate. The results indicated that: (1) students were mainly responsible for their own learning; (2) activity sheets were used to relate new experiences to prior knowledge; (3) this learning environment was designed to encourage student understanding rather than rote learning; (4) activity sheets and note guides were used to engage students in actively constructing their own learning; (5) a framework for student learning was developed; (6) additional cues as to the level of cognitive demands came from the students and led to different classroom strategies being adopted to improve learning; (7) the syllabus and assessment structure controlled the time spent on each topic; and (8) this learning environment promoted students' self-esteem. (TW)

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The Teaching-Learning Environment in a Student-Centred Physics Classroom

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INTRODUCTION

For cognitive growth and development to occur within a classroom it is necessary for a teacher and students to work together to establish an atmosphere conducive to learning. Watt & Watt (1981) considered that an ideal learning environment results from "the balancing of many needs, interests, ideas, values and constraints and is continually shifting to reflect new balances among these forces." To explore in detail how such forces may relate to a particular classroom environment an ethnographic-interpretative research strategy was adopted in our study of a single physics classroom. This approach was selected as it was assumed that each classroom formed its own local microculture and even, many "local" features could change over the period of a study (Erickson, 1986). The adopted research strategy allowed continuous observation of both teacher and student behaviour to be undertaken by several observers over a period of several weeks.

One modification of the normal ethnographic approach adopted in the present study was that the physics teacher participated in the post-observational discussions and the weekly meetings of the "official" observers. Hence observers in the initial stages of the study were able to make detailed notes on the initial teaching-learning strategies that the teacher had previously developed over a period of four years of teaching physics to similar age groups. This teacher, however, by becoming a participating member of the research team, was able to reflect on existing practice (Schon, 1983) using the field and interpretative notes circulated and discussed by all team members at weekly meetings during the period of observation. The "external" researchers, thereby, acted as coaches (Baker & Shavers, 1984 and Tobin (1987a) in supplying the teacher with substantial feedback on pedagogical strategies, use and effectiveness of teaching material and so on. Allowing the teacher to participate openly in this way led him to make changes in his teaching-learning procedures. The consequent influence of these changes on the classroom environment could then be observed and interpreted.

METHOD

The observed group consisted initially of 24 secondary-school students who had decided to take physics as one of their 5 academic subjects in the first year of a two-year course leading up to the Western Australian Tertiary Entrance Examination (TEE). Two additional students joined the group during the first semester. The observers (on most occasions 2 observers were present) made field notes during the whole of each of the four 50 minute physics lessons which took place each week. Data were gathered during two 6-week periods followed by two 3-week periods when no classroom observations took place. Additional data were provided from students' working files and tests, teacher notes on lesson planning and distributed class notes, information from student questionnaires and interviews with students and the teacher. Lesson

espisodes were also tape recorded to provide more precise data for analysis. All four researchers interacted as soon as possible after the collection of these data so that they could be adequately and reliably interpreted while " fresh in the mind". Such immediate interaction provided a focus for subsequent observations and construction of assertions, the validity and reliability of which were carefully considered by triangulation using supportive data from as many sources as possible and by congruence among the researchers' data.

NATURE AND ORGANISATION OF THE STUDENTS' LEARNING ENVIRONMENT

The physics teacher, in his first lesson , attempted to establish clear expectations, routines and rules. Particularly the students were expected to "stand on their own feet". They were to be less reliant on the teacher as a transmitter of information, in a formal teacher-centred way. They were to be mainly responsible for learning through their own efforts by making effective use of provided teaching material. Each student was given a "study guide" for each topic, which consisted of the following elements: (1) the sub-topics for a topic area; (2) an approximate time allocation for each sub-topic; (3) the relevant text references; (4) appropriate problems and questions; and (5) laboratory activities (if appropriate). An example of a study guide for the topic "Waves", which was produced about half way through the semester, is given in Fig. 1.

Fig. 1
Example of the Initial Format of the Study Guide for "Waves"

Characteristics of Waves

Major Objective: To be able to describe waves mathematically, diagrammatically and verbally

Specific Aims: Explain the meaning of the terms phase, wavelength, amplitude, wave speed, frequency and period.
Apply the wave equation to situations involving waves.
Explain the meaning and relationship of wave fronts and rays.
State how to represent all periodic wave motion.

Keywords: sine curve, displacement-distance graph, phase, wavelength, amplitude, speed, frequency, period, displacement, equilibrium, unit time, simple harmonic motion, vibration, execute, oscillation, cycle, $\tau = 1/\gamma$, $C = \gamma\lambda$, crest, compression, wave front, circular wave front, plane wave front, rays.

References: Anderton 9.5
Murphy et al., 15.2, 15.3, 15.4

Figure 1 (continued)

Questions and Problems

Compulsory	Anderton	9.4:3; 9.5:4.
	STAWA	Set 27: 1 - 10
Optional	Anderton	9.4 9.5
	Murphy et al.	Ch. 15 1-7
	Gardiner	Set 22 3, 4.

Note: Anderton refers to the main physics textbook used by the students;other textbooks available were Murphy et al. and Gardiner. STAWA refers to the physics problem book from which students could select relevant questions.

Thus students were requested to read certain specified references from their textbook(s) and to undertake specific problems based on such reading. As will be discussed later, these study guides became more structured and sophisticated, as a result of feedback discussion from the research team on the observational and interview data, in directing students as to the most salient keywords and learning outcomes in a particular topic.

REPORTING OF RESEARCH DATA IN TERMS OF GENERATING AND TESTING ASSERTIONS

From field notes recorded and reviewed by more than one observer for every lesson and supplemented by interview data, audiotape transcripts, teaching- material information and questionnaire the following assertions were put forward. These assertions were confidently established as a result of analysing and discussing all the data in team sessions.Some of the relevant evidence for supporting a particular assertion is given in this paper. This procedure of interpreting ethnograhic data in terms of the least redundant number of assertions follows that suggested by Erickson (1986).

Assertion 1: Students were mainly responsible for their own learning.

At the outset of the semester each student was given details of the type of activities in which they would be engaged. In the teacher's introduction to the physics course, he discouraged the mere learning of formulae, rules,and algorithms. Memorization by simply acquiring routines was to be regarded as a "lazy habit". Emphasis on understanding "by getting away from learning rules and formulae would lead to enjoyment in physics."Clear management of students' learning by the teacher was designed to enable them to adopt study habits that would

allow them to concentrate on understanding. Onus, however, was to be placed on the students' own efforts to make efficient use of the provided resource material.

In an initial document presented at the beginning of the semester (the nature of some of these activities were later modified during the semester) the following student activities were specified: (1) Write your own summary notes (preferably at home); (2) Solve problems and check answers (at home); (3) Answer written questions and check (at home); (4) Discuss your work with other students; (5)Plan laboratory activities; (6) Perform formal laboratory activities and write them up; (7) Lectures (minimum); (8) Class discussion; (9) Read a variety of texts (preferably at home); (10) Seek assistance from teachers (maximum); (11) Participate in small group lessons / discuss with teacher (maximum) (12) Complete activity sheets. Thus there was to be mimimum emphasis on direct transmission of knowledge and this would mainly occur when a student voluntarily sought help from the teacher.The teacher, however, had not ruled out the possibility of minimum formal transmission of learning through lectures and class discussion.

From the very first lesson the students were encouraged "to ask questions and not to mind not knowing; best way of learning." So the teacher (and observers) could be freely approached for assistance and they were reminded that additional help could be sought among friends, parents and older siblings. He stressed the student centreness of the learning process by stating that "you (the student) stand on your own feet; the teacher's role is to make it easier." He further stated that "there will not be too much listening as it is difficult to pitch a lesson at the appropriate level for everyone." He encouraged a maximum seeking of assistance from teacher(s) by emphasising that "there is nothing wrong in asking." In the early lessons of the semester the teacher continued to reinforce his teaching approach,e.g., in the third lesson he explained how they should keep their files with notes which they had made from the textbook, exercises, tests and laboratory work.They were advised not to spend time doing problems that were too easy and that there was no need to do every problem. Although the teacher, at a later stage, gave more specific guidance to students in organising their learning as a result of his own reflection, following feedback from the research team, these changes did not reduce the overall responsibility of each student for his own learning.

As the semester progressed students responded to a questionnaire on their study habits and this was followed up by an interview. To one question asking students if they felt responsible for their own learning by making use of their textbooks and problem book each week without being asked specifically to do so by their teacher, 23 of the 24 students considered that they accepted such responsibility. Only one student showed some ambivalence. The majority of students also liked being in charge of their own learning as only 3 responded negatively but another 4 were somewhat ambivalent. In addition, a considerable majority of students, 18 of them, were of the opinion that their present learning strategies made them work harder than if they had to rely on more formal teacher direction and control.

Assertion 2: Activity sheets related new experiences with prior knowledge

To acquire knowledge and understanding students have to subsume (Ausubel, 1968) new experiences into their existing cognitive structures through related concepts or ideas and ,thereby, to relate aspects of a new topic with existing information and experiences stored in the "long-term" memory (Stahl, 1987).As shown in Fig.1 topic guides directed students to appropriate textbook sections to study. If no other assistance was availabe other than the textbook(s) students' understanding of a topic would largely depend on the suitability of the textbook for independent, individualised learning. To supplement the padagogical content of the textbook(s) the teacher provided activity sheets. These were designed to translate the content knowledge provided by the textbook(s) into more familiar ideas leading to greater conceptual understanding. The textbook(s), of course, continued to be the basic source of ideas by which students became mentally engaged.

An example of a typical activity sheet by which the teacher helped to develop student understanding of the concept "relative motion" is shown in Fig. 2. Here students started their thinking on a particular

Figure 2

An Activity Sheet on "Relative Motion"

To determine how to solve relative motion problems let's consider some scalar problems.
e.g. Angela has $32.00 and Rebecca has $20.00. How much does Angela have relative to Rebecca ($A/R)?_____

Everton (an English soccer team) scores 3 goals to Liverpool's 2 goals. How many goals did Everton score relative to Liverpool? (G E/L)?_____

(The rule was then applied to vectors)

If Vince is travelling at 5 m/sec North and a wind is travelling at 3 m/sec South he feels that the wind has a different velocity than this. Explain.

concept at a cognitive level that made use of familiar concrete ideas. The names used,e.g., Angela and Rebecca,in these familiar situations were those from within the class. The teacher spelled out, in one of the discussion sessions, the purpose of these activity sheets as "making use of students' prior knowledge by allowing them to think through the ideas- they may get them wrong- so that they are in a better position to read the textbook. The textbook confirms and consolidates students' views and responses in the activity sheets."

When interviewed about their opinions of classroom learning procedures students universally liked the activity sheets. Even when

they appeared to be somewhat long they were considered good in that "they gave you extra practice and reinforced correct ideas and gave you confidence."

Assertion 3: The learning environment was designed to encourage student understanding rather than rote learning

There is evidence from other "interpretative" research studies (Tobin et al., 1987; Tobin, 1988) that the cognitive demands of many science classrooms were rather low. For example, in a physics classroom, 80% of the students' time was spent on problems using mathematical formulae. As indicated in Fig. 1, a considerable proportion of students' time involved solving problems from both textbook(s) and the book "Physics Problems", the latter published by the Science Teachers' Association of W.A. Although the cognitive demands of many problems might appear routine in their use of standard formulae or algorithms, students might very well be applying the procedures with understanding. From the present teacher's use of activity sheets there was considerable evidence that difficult ideas were transformed into understandable formats for students. Even though the teacher may make some effort to ensure understanding there is always the tendency for students to adjust their learning strategies (McConkie, 1977) to suit the cognitive demands of problems and if these require only the memorization of formulae or procedures real understanding may suffer. These difficulties could only have been overcome through the introduction of more searching, qualitative type questions rather than merely applying formulae.

Although a student's understanding of a task is closely associated with learning time (Bloom, 1979; Carroll, 1963) the teacher specified the same learning- time interval for each student for a topic. Tobin (1987) from a review of five separate studies in high-school mathematics and science classrooms also noted this tendency and asserted that "teachers endeavoured to cover the curriculum in the prescribed time whether or not learning occurred." In the present study all students took a scheduled topic test at the end of a fixed period of time. The teacher accepted this situation by stating that "at any one time students may be at different stages through a study guide. All students, however, must complete the study guide for each topic before the schedule topic test." Of course as the allocation of students' learning times outside class time was their own responsibility the overall time devoted to a topic could have reflected their level of understanding.

Data from the Study Habits Questionnaire indicated that 19 students emphasised understanding of physics rather than mere rote learning, while 2 were ambivalent in that they were not always consistent in their learning behaviour. Their reponses also showed that the present physics course made 8 more of them stress understanding than in their previous science courses. A follow-up interview elicited several interesting comments on reasons for stressing understanding:

"You have to possess a bit of common sense to work out why you have those formulae." This response could have been related to the

nature of the teacher's activity sheets in which ideas were familiar and, thereby, appear "common sense".

"Physics is easier if you understand the ideas". This statement is a reiteration of the teacher's philosophy.

"If you know how to work formula out you understand the thinking behind it". Here the student had a clear conception of the term "understanding".

On the other hand, a few students admitted that they adopted a "short-hand" strategy. For example, one student stated "I learn the formula even if I don't understand the ideas behind it." There is evidence from the questionnaire data that some students' difficulties arise not from the lack of desire to understand the ideas but because help is absent at home and there is some difficulty finding more time for homework.

Assertion 4: Teaching resources engaged students in actively constructing their own learning.

The teacher's instructional role was firmly based on a constructivistic paradigm of the learning process. Cognitive constructivism implies that human psychological functioning is active rather than passive, is individualistic and that inner mental states rather than external stimuli control behaviour. Constructivism suggests that humans act upon their environment rather than simply reacting to it. Individuals are continuously seeking meaningful interpretations of physical and behavioural objects present in their environment. The role of personal construction in the development of science itself is recognised in current philosophers of science (Kuhn, 1970). Traditional teaching (Pope & Keen, 1981) methods, however, have often conformed to a cultural transmission strategy in which students are no more than receivers of information rather than mentally active participants in the process.

Even if students are given opportunities to engage actively in learning tasks they may not be motivated to do so. Pope & Gilbert (1983) observed that "It is not sufficient that a body of knowledge from a textbook or given out by the teacher be accepted unquestioned by the student. Students must find this body of knowledge true for themselves. They must be able to incorporate it within their views of the world." Rather than simply guide students as to sections in their textbook(s) to read and make notes, as had occurred in the early weeks of the present study, the teacher devised a new more elaborate and precise system of learning instructions for each topic. These study guides included major objective, specific aims and important key words and phrases for each topic. Notetaking by students became less random as they now concentrated on specified concepts, relationships and propositions. An example of such a study guide is given in Fig.3.

This guide enabled them to focus their thinking on certain clearly defined objectives and to form their own understanding of certain specified concepts from reading their textbook(s). Students themselves constructed their own notes and, thus, became mentally

engaged in establishing conceptual understanding. In this task students were encouraged to seek help both from teacher(s) in class and others at

Figure 3

An Example of the New Study Guide: Types of Forces

Major Objective: To understand the difference between applied force and net force.

Specific Aims:
1. To list the major types of applied forces.
2. To explain what is meant by a force "acting over a distance".
3. To discuss the meaning of Friction, Tension and Reaction (Normal) Force.
4. To state the difference between Static Friction and Kinetic Friction.

Key Words and Phrases: Applied force, electrical, gravitational, nuclear, magnetic, action at a distance, net force, resultant force, unbalanced external force, friction, tension, reaction force, normal force, static friction, kinetic friction, sliding friction, rolling friction.

at home. An additional aid to students reading a section of a textbook was the teacher's provision of a summary of its contents in terms of keywords, relationships, laws and so on. An example of such a guidance sheet is shown in Fig.4. These guidance sheets enabled students to

Figure 4.

An Example of a Guidance Sheet

Textbook - Anderton,J. Fundamental Physics (Longman Cheshire, Melbourne, 1983)

Chapter 5: Newton's Laws of Motion

5.1 Newton's First Law of Motion

Keywords: Dynamics, Sir Isaac Newton, Galileo, natural state, external agent, Newton's first law of motion, constant velocity, theory, deductions, generalisation, inertia, quantitatively, mass, weight, force.

This Section
1. Talks about what happens to objects when no external agent acts on the object.
2. Discusses the meaning of inertia.
3. Explains difference between mass and weight and how inertia depends on mass.
4. Defines and discusses the term force.

select and read relevant material from a chapter of their textbook and, thereby, reduce haphazard selection. As discussed earlier (assertion 2) students became mentally engaged in a learning task through Activity Sheets that made them think through ideas from first principles by using real life situations within their own experiences. Only when students asked for help did the teacher intervene in the thinking process

To engage students further in a topic, several textbooks were available in the laboratory from which they chose one to provide a further overview of the topic they were exploring. This assignment came at the end of the period of study allocated to a topic. A typical example of an Overview Sheet is shown in Fig. 5. Such an overview

Figure 5

An Example of an Overview of a Topic

Newton's Laws of Motion

1. You will be allocated one physics textbook to review
2. The appropriate chapter or chapters are to be found. Key words to assist you find the appropriate section are:
   Dynamics, Sir Isaac Newton, Newton's first law of motion, inertia, mass and weight, applied force, net or resultant force, tension, reaction force, friction, external/internal force, Newton's second law of motion, acceleration, F = ma, Newton, Newton's 3rd law of motion, action/reaction, lift (elevator) problems, bodies connected by strings.
3. The relevant chapter should already be devided into sections, if not do this yourself (approximately 6 sections).
4. On the top of the sheet state the name of the book and author.
5. For each section you are to:
   (a) List key words, unusual words, etc.
   (b) Summarise in approximately 3 sentences what the authors are talking about in the section.

allowed students to make use of their new understanding of a topic by applying it to a new textbook. This strategy reinforced the new learning especially by students seeing novel treatment of the topic from that already learned.

Assertion 5: A framework for student learning was established.

To enable students to work on their own in an efficient manner much effort was required by the teacher. Much detailed guidance and help needed to be provided if understanding was to be encouraged through maximum student engagement in learning. In the initial stages of this research students made their own notes on a topic using Study Guides which merely specified sections and problems to complete from textbook(s). No particular minimum demands were made on the students. A review of the students' files by the end of the first 6 weeks of the study revealed that a considerable number of these files were inadequate for revision purposes. Typical comments made by members of the research team on students were:

Student 1: "Thin file; most of contents are hand outs from the teacher; appears incomplete; many problems not marked and/or checked; working out of problems looks to be well set out; no notes on his work; no practical work report organisation of file would make it difficult to study from."

Student 2: "Notes-close to the textbook but not identical to it-fairly full-logically presented; Questions-all questions attempted but not all marked; Overall Impression- a lot of care, effort and thought have been put into these notes. They are beautifully set out using two colours; may well be more than she really needs though."

These reports on the files of a "poor" and a "good" student, respectively, indicated some weaknesses in their composition. In making up notes, as directed by a Study Guide, both students stuck rigidly to the words of the text. Also, problems that were solved were rarely corrected and consequently little positive feedback to the student was provided. The teacher, on examining the students' files at this stage, wrote comments in the students' files such as "Far more written output required"; "Your notes and exercises need to be expanded."

By the second half of the semester the teacher was aware of the limitations of the Study Guides and the necessity to modify these and to provide additional written help in guiding student learning. An example of the new Study Guides is shown in Fig.3. When these were first introduced with the topic of "Waves" he suggested that the students read Chapters 9 and 10 of the class textbook Anderton first of all and then another book. The reason given was "that some books go too far; Anderton defines the course very well; you may otherwise read a section in another book that may be irrelevant. See if the other book expands on a topic Anderson does or deals with in a different way."

The teacher in a subsequent lesson attempted further to systematise the procedures which students should adopt. They were not to copy notes directly from the textbook; they should correct their work and seek help from teacher(s). He put on the blackboard the general precedures they should follow: (1) Activity Sheet; (2) Reading-Rough Notes; (3) Check Activity Sheet (tick corrections); (4) Notes and Problems (should be corrected). His oral instructions were that "There

is too much time taken up with class notes; you should find more time to talk to the teacher." He stressed that they should use "keywords" in their notes and instead of writing out paragraphs they should do "word diagrams" (an unsophisticated term for concept map). Taking an example he explained on the blackboard how a word diagram could be used to link concepts.

Students were asked in a questionnaire towards the end of the semester to describe briefly any changes which had taken place during the first semester which had helped to improve their learning and understanding. They perceived certain changes as providing considerable improvement on earlier procedures. Examples of their responses were:

> "Introducing activity sheets helped making understanding concepts easier while note guides helped specify which sections of the topic were more important- made the topic as a whole clearer."
>
> "With the introduction of note guides, study guides, activity sheets and the overview activities, I found that I was able to improve my learning and understanding of physics with the help of these... and also by working at my own pace."

They generally welcomed the changes away from what one student described as "the amount of note taking" previously undertaken.

An interview again undertaken at the end of the semester yielded information on students' preferences for different learning activities. They prferred "completing activity sheets". Two activities that came equal second in preference were "taking rough notes/reading texts" and "completing study guides". Less popular were the activities "answering questions" and "solving problems". The least preferred activity was the "overview activity". Of course students might have been considering the relative importance of activities rather than regarding any one as not being particularly useful. One student, for instance, stated that the "overview" "gave a good indication of what the topic was about" while another thought that "overviews which were introduced were a great help." Students in the interview expressed the desire for more activity sheets which showed that these were welcomed additions to the material in the textbook(s). This is not surprising in that it was through these activity sheets that the teacher contributed his specific pedagogical content knowledge to allow the students to be more mentally engaged in a topic.

Students generally appreciated the changes which the teacher had incorporated into his organisation and management of their learning. These changes enabled them to structure their learning along very clear boundaries. More importantly, however, it allowed them sufficient scope to analyse the relevant sections of the textbook(s) with more comprehension. Also, students now knew what was expected of them in terms of reading, completing activity sheets and solving problems. A minimum of work was to be finished in the allocated time for a topic. They were now working within a framework of which they generally approved.

Assertion 6: Additional cues as to the level of cognitive demands come from the students and lead to different classroom strategies being adopted to improve learning.

In a review of classroom process-product research in the area of science teaching Power (1977) discovered inconsistencies in many of the studies' findings. He stated, however, that "the frequency of teacher praise, indirectness, higher cognitive questions and of pupil-centred inquiry does not invariably lead to increased student achievement and satisfaction. Nevertheless, the research does indicate that most students suffer if lessons have no apparent structure or purpose, if much time is wasted due to inefficient management or control, or if the teacher is poorly prepared and adopts a passive role in the classroom." The essential criteria for effective science teaching appear to be efficient management, good use of student time, an active role in the classroom and good lesson preparation. The physics teacher's role will now be discussed.

Although the student was regarded as ultimately responsible for his/her own learning this teacher adopted a very purposeful, if not explicitly active, role to ensure that such learning took place. Activity from the teacher's viewpoint did not entail the direct transmission of knowledge through oral interaction with the whole class but being responsive and sensitive to the individual needs of all the students. In discussions with the research team the teacher expressed his dislike of "whole class" teaching by stating "Just think of the students going to 7 classes per day and teachers talking to them in each lesson; I'm not convinced that speaking to the whole class is effective; I'm convinced that many kids don't listen..I'm well prepared when the class will run by itself; it's not possible to run a class in this way if you are not well prepared and confident in your subject."

The teacher intervened in the learning process whenever he considered it apportune. For example, in one of the earlier lessons he advised "You should start on questions that are going to be a challenge.". He then chose a problem with which, he suspected, some students would have some difficulty. Looks of puzzlement appeared on many of their faces and he responded by inviting those who required help to come up to the blackboard where he helped them with the solution to the problem. Other students continued with their work although some of them were also listening to the teacher's instruction taking place at the front. The teacher justified his use of "small group" teaching by stating that difficulties arising from a particular problem would most likely only involve a small number of students. The composition of such groups was dictated by the nature and complexity of the problems and by the personal decisions of students to seek help.

At first the strategy suggested for homework was "to read, highlight, make rough notes, do STAWA problems, make final notes and do extra reading." Notes were expected to be handed in at regular intervals. By lesson 6 students seemed to know what was expected of them and how to find their way through a guide. One observer expressed the

opinion at this stage that students relied "on their internal feelings as to whether they have the answers correct. Their confidence and self-reliance are both very pleasing to see but it does mean that gross misunderstanding could pass unnoticed." To supplement for the inadeqacies of the textbook(s) the teacher, about a fortnight after the beginning of the semester, introduced activity sheets. For example, to help students to understand the rules, as given in the textbook, for deciding on the number of significant figures to include in denoting the accuracy of a measurement, the teacher constructed activity sheets. These worked well as they appealed to the students' own body of knowledge and made use of the teacher's own expertise and experience in providing appropriate pedagogical content knowledge.

The provision of activity sheets consequently became one of the most frequent procedures by which the teacher intervened in the insructional process. For example, with a new topic on "vectors" the teacher admitted to the class that "a different approach was going to be adopted as a result of feedback and to avoid problems encountered so far." In other words he was very honest and open with students in providing them with reasons for any changes in procedures. Activity sheets also allowed laboratory activities to be incorporated into the physics course. An example of such an activity sheet is shown in Fig.6.

Figure 6

An example of Activity Sheet involving Laboratory Work

LONGITUDINAL WAVE MOTION

To observe a longitudinal wave use a SLINKY SPRING. With a partner stretch the spring (NOT TOO MUCH). One person squeezes together a section of the spring (between 10 and 15 cms.) and releases it. A pulse (disturbance) should travel along the spring. Repeat this procedure a number of times carefully observing the spring. Imagine a photograph is taken of the middle section of the spring as the pulse reaches the middle. Using simple vertical lines to represent the spring draw what you would see in the photograph. (Include the section of the spring that has not yet been disturbed and that section that has returned to its original state after the disturbance.)

The teaching strategy, which the teacher used on very rare occasions, was instruction of the whole class. This occurred only if he received feedback from the bright students that they were having some difficulties with understanding a topic. Such intervention implied that the whole class was having learning problems. Once these problems had been dealt with in a whole class situation the teacher reverted back to his normal strategy of helping students as they worked independently or in groups. He did not impose his attention on them without students first seeking his assistance. The teacher resisted the temptation of intervening in the student's learning process until called upon by the

student. Only when the whole class required help did the teacher intervene directly.

In a final conclusion to their review of effective teaching strategies Brophy & Good (1986) stated "Student achievement occurs more readily in classes where they devote more of their time to being taught and supervised by the teacher rather than working on their own. Thus the teacher presents the content to the students himself/herself rather than relying on the curricular materials to do so; it is best for the teacher to give the material through brief presentations followed by discussion or application." It would appear from this conclusion that the physics teacher was adopting teaching procedures that would not be very effective. The students, however, in this physics class are not left on their own and the time they devote to learning tasks is maximised by self-help strategies. For example, any student having genuine difficulties with a topic could either get personal attention directly from the teacher(s) or join a small group at the front for more direct instruction. Consequently, the student not requiring help could make more efficient use of his/her time.

Also, if the whole class appeared to be having difficulties the teacher did not hesitate to intervene more directly. In addition, the teacher did not allow the published curricular material to be the sole source of student learning but provided additional learning material through "activity sheets". Questionnaire data revealed that students asked the teacher for help, on the average, 3 to 4 times per week. Some, 8 students, sought help from outside the school, from parents, siblings and so on. Others, of course, consulted friends within the class. Hence, both time for learning and opportunities for consultation with others were increased through the teacher's strategies.

Assertion 7: The syllabus and assessment structure both control the time spent on each topic.

The physics teacher for Year 11 followed a syllabus which was constructed by the Joint Syllabus Committee of the Secondary Education Authority of Western Australia. Certain constraints and emphases were specified in the syllabus and these were stated in the following terms:-

> The aim of the syllabus is to delineate the fundamental laws and principles of physics and to introduce the student to the use of these principles in the solution of simple numerical and algebraic problems. Derivations of formulae will not specifically be examined, though these should be demonstrated and their basis understood..... Part of the syllabus lists a number of formulae at the end of each section. Problems involving these formulae may be set in the examination. It is expected that students will be facile in manipulations involving at least this list of formulae...The specification of such a list is to indicate what is considered a minimum level of mathematical application.

The syllabus, thereby, strongly emphasised the connection between principles of physics and their application to the solution of numerical

and alebraic problems. Although students were expected to be able to derive formulae, they would only be asked in the final examination to solve problems by simply applying formulae.There appeared to be a strong mathematical and procedural bias in the form of the examination. Such emphases in learning tasks were discussed by Doyle (1983) who classified tasks according to their learning demands,namely, memory, procedural (applying a formula, procedure, routine or algorithm), comprehension and opinion. An examination that simply demanded the student to produce answers by using a standard routine,e.g., applying a formula, was unlikely to test understanding. "Facile manipulation", as stated in the syllabus, of formulae was no substitution for genuine understanding.

The syllabus suggested that the following core topics, in Year 11, should be completed in less than 1½ semesters: units and dimensions, mechanics, heat, wave motion and light, and electricity.The rest of the second semester (6 to 8 weeks) was to be devoted to optional areas provided in the syllabus. Furthermore, a school based assessment in physics was required in Year 11. These external factors dictated both the time to be spent on a topic and the structure of the examination components as the teacher wished the latter to be a reflection of the format of the Tertiary Entrance Examination (TEE) which students would take at the end of Year 12. The time to be devoted to a particular topic was specified in the Topic Guide, which contained also the names of the sub-topics and text references. The time allocation for each sub-topic was no more than 1 or 2 classroom periods and adherence to this time schedule put considerable pressure of both teacher and students to complete each sub-topic on time.

As to be expected such time constraints put undue pressure on the slow learner. For example, in response to the Study Habits Questionnaire one such student wrote "There is too much homework each week; topics are covered too quickly." Another student added "more time is required for full understanding." Altogether 9 students mentioned the lack of time to complete their work as one of the special difficulties with the course. Also one student mentioned the large gap between their physics lesson on a Thursday and the next one of the following Tuesday. If they did little work on their physics over the weekend considerable forgetting could take place. A more individualised allocation of time to allow each student to achieve full understanding of a topic would likely have been a more efficient arrangement (Bloom, 1976) but such a strategy could have resulted in some students not completing the whole syllabus in the required time.

The other main constraining factor was the requirement that a school-based assessment of students should be incorporated into the course. The assessment of the Year 11 physics course had four elements as follows:-

(a) Examinations (end of Semester I and end of academic year:50% These would reflect exactly the Tertiary Entrance Examination (TEE) format. The end-of-year examination would assess both work in Semesters I & II.

(b) Topic Tests (24%) These would consist of "one or two period" tests at the end of each topic, containing a mixture of problems, multiple choice and descriptive questions.

(c) Laboratory Test (10%) This test would consist either of a laboratory activity which the student would plan and write up before the laboratory session or of a test of the student's practical (hands-on) skill.
(d) File Work and Laboratory Reports (16%) These were to be assessed not for accuracy but for such aspects as completion, effort, setting out, corrections,etc.

Thus three quarters of the overall total marks went to formal examinations at the end of the school semester and to topic tests taken at regular intervals throughout the course. Although files and laboratory reports would provide the most reliable evidence of the students' progress and understanding, these received relatively less weight in proportion to the more formal parts of the examination.This emphasis was reflected in the instructions given to physics teachers in the syllabus.For example, the syllabus stated that "derivations of formulae will not specifically be examined" and formualae to be memorized were provided in the syllabus. One statement in the syllabus hoped that "students will be facile in manipulations involving at least this list of formulae"(Physics (Year 11) Syllabus). The evidence of such low cognitive demands of tests was shown in an interpretative study with a chemistry teacher by Tobin et al.(1986). Thus even when a teacher stressed understanding and used various strategies to overcome rote learning, as indicated in this study, the external examination as specified by the Educational Authorities might not stress these same objectives.

Assertion 8: The learning environment promoted students' self-esteem

The establishment of a learning environment that promoted the students' self-esteem appeared to be one of the main aims of this physics teacher.During one of the research team's discussions the teacher stated "One of the important goals in education is to improve a student's self-esteem". This aim was summed up with regard to any student in his statement "I respect you (the student) as a learner, you want to learn and have considerable intelligence and you are going to learn." In other words, he showed confidence in the student's ability and desire to learn. It was up to the teacher to create the conditions by which the student's learning potential could be promoted.In the first place students should feel responsible for their own learning. Questionnaire data indicated that all students felt this responsibility. Furthermore the majority of them (15) liked being in charge of their own learning but an additional 4 students were ambivalent. This left, however, a small minority of students who did not enjoy such responsibility.

Within the classroom the teacher left it to the student to decide to seek help. The teacher did not believe in "prying" on students, looking at their files over their shoulders or in any way making them uncomfortable. He resisted intervening directly and uninvited into a student's learning process. Little "notoriety" was

given to individual students; there were no apparent favourites; and no critical comments were made to students for demands made on the teacher. The success of such strategies has been explored by Shymansky and co-workers (Shymansky & Penick, 1981; Shymansky, 1976) in a range of classrooms from K to grade 8. They found that, even with these younger students, those who were taught by non-directive science teachers spent as much as 90% of their class time on-task with learning materials provided. Often this percentage on-task time was superior to that which occurred within highly directed classrooms where there was considerable teacher choice and guidance of activities. Surprisingly it was found that students appeared to remain on-task even more when the teacher interacted less! Also it was noticed that students with more freedom to interact on their own with material achieved as well or better than the more "directed" students.

As the onus for the completion of work was placed on the student, s(he) was not waiting for teacher instructions. Students were rarely "at a loss" as to what to do or were waiting on others to complete a task. They could continue working at their own pace. There was a high proportion of on-task behaviour at all times. The presence of additional adult observers, of course, could have had a "daunting" effect on students' normal classroom behaviour especially if these observers were more inclined to initiate contact and examine their progress than the class teacher. There is, however, evidence (Herty-Larsarowitz, 1984) that in more co-operative, investigatory science classroom one-third of student-student interactions were on-task as compared with only 13% in traditional science classrooms. Also, Tobin (1985) noted that student engagement was higher in science classes where materials and equipment were used to provide students with opportunities to practise and achieve proposed learning objectives. The class did get used to the presence of observers and the relative silence of the first weeks were replaced by a more relaxed atmosphere with more social interaction among students. Observers also became more sensitive of the students' desire for less direct observations of their individual efforts and to interact with students only when requested. This fitted more readily into the pattern of interaction adopted by the teacher.

Learning was encouraged to take place outside the confines of the classroom. The teacher expected students to undertake certain activities at home such as writing up summary notes, solving and checking problems, answering and checking questions and so on. Each student it was hoped ought to make efficient use of time in doing work within his/her rate of learning. When asked whether or not these arrangements for independent learning made them work harder, 17 students replied in the affirmative while 6 responded negatively. As some of the latter group might work hard even under different arrangements these results altogether provide a strong endorsement of the existing learning environment.

Moreover, the majority of students (19) maintained that they continued trying to get the right answer to written problems even when they failed several times. In addition, almost all of them sought help when they continued to get the wrong answer. Thus, the students indicated that they were not afraid to approach adults for help with

their learning. This was just the type of non-threatening environment which the teacher wished to establish. The questionnaire also explored how successful and how happy they felt in this environment. Thirteen students considered themselves successful in understanding their physics,5 were ambivalent, 2 students regarded themselves as unsuccessful and 2 did not respond. As to their progress on the course 2 students were very happy, 12 fairly happy, 3 were either fairly happy or slightly worried and 5 students were slightly worried. Later tightening up of classroom procedures, after the results of the questionnaire were known, to include compulsory problems and specific learning aims together with additional help through activity sheets, were designed to assist students who were worried by their progress.

The teacher was very sensitive to the likelihood of a few students dominating classroom interactions in a "whole class" situation. Indeed in discussions with the research team he was able to label students (5 in all;3 boys and 2 girls) whom he regarded as potential target students. Observational studies (Tobin & Gallagher, 1986; Tobin et al.,1987a) confirmed this tendency of science teachers interacting with relatively few students. By the teacher only resorting to "whole class" teaching on rare occasions when necessary, students' self-esteem was not under constant threat by certain students "hogging the limelight". A more productive and non-threatening environment was established by students not having to compete with each other in seeking teacher attention, answering oral questions in front of all their friends and so on. On the whole, individual students worked at their own pace and sought teacher help when difficulties arose.

The teacher encouraged co-operation among students by stating in his initial instructions that they should discuss physics ideas and problems with each other in small-group discussions. Thus students could help each other to verbalise and elaborate on their own thinking in a non-threatening situation to friends in addition to the teacher(s). Moreover, the teacher's trust in his students that they would carry out independent learning within and outside the confines of the classroom, was borne out in their behaviour on the very few occasions in which the teacher was not present in the room. Students even with the absence of the teacher were generally on-task. Such behaviour readily arose because the students were capable of proceeding in their learning from the point they had previously left off without having to rely on the teacher's instructions. Furthermore, if the teacher happened to be absent from class he would leave an on-going, active and self-sustaining environment that allowed a different teacher to take over readily the students.

MAIN CONCLUSIONS

There are several aspects of this physics teacher's organisation of the learning environment which will be of special interest to the practising teacher who wishes to get away from a "spoon-feeding" strategy of teaching. Especially worth noting in this study is the degree of trust which the teacher places on the good sense of students to accept responsibility for their own learning. The teacher, however, must be sensitive to the learning needs of the students and provide

teaching material and continuous help whenever these are required. The teacher must also be flexible and, if necessary, change his plans to fit in with the individual needs of the students. The present teacher is very much aware that he has to improvise his teaching material and that he is experimenting and adding to it all the time. He would like to be in a position in which he would have a complete set of notes to give to students but this is going to take some years to achieve. The assertions supported by observational, interview and questionnaire data show that the teacher's inculcation of an appropriate learning environment is still an on-going situation requiring continual modification.

There may, of course, be weaknesses in the strategies that the teacher has adopted. Its success depends on the degree of trust that the teacher can establish with the students. These learning strategies work particularly well with a well motivated class whose members have high-level aspirations on leaving school. The present physics group selected physics as one of their 6 subject options in Years 11 and 12 and, consequently, they wanted to be successful in their chosen subject. With a less motivated class a teacher may have more problems in getting students to fulfil their commitments. Also, very weak students may make considerable more demands on the teacher than the more able. Some of these weaker students may be too embarrassed to seek the teacher's attention as often as they should. With some groups great demands may be made on the teacher's time especially if many students require considerable attention to cope with learning difficulties. From the evidence of this present study, however, classroom strategies concentrating on the quality of the students' learning are generally preferred by well-motivated students and lead to an environment which enhances their self-esteem, responsibility, behaviour and academic performance.

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